for immediately after;" a few slang terms, such as "gimcrackeries" and "nicknackeries," and a few technical terms that might as well have been translated in accordance with common use. "Shoulder-blade" and "blade bone" will do well enough for scapula; "collar-bone" for clavicle; "shinbone" is quite endurable; but "spoke-bone" for radius, is rather new; and "rump-bone" for sacrum, whatever it might have been in the days of Cromwell and the Long Parliament, is at present, at least in surgical terminology, rather obsolete. The mechanical execution of this work is also quite commendable. J. W.

ART. XIII.—*Lectures on the Physical Phenomena of Living Beings.* By CARLO MATTEUCCI, Professor in the University of Pisa. Translated under the Superintendence of JONATHAN PEREIRA, M. D., F. R. S., &c. London: 1847. 12mo. pp. 435.

IN 1844, Professor Matteucci was appointed by the government of Tuscany to deliver, in the University of Pisa, a course of lectures on the Physical Phenomena of Living Beings. These lectures were subsequently published; and their popularity is attested by the fact, that they have already passed through two editions in Italy, and one in France.

The present translation has been made from a copy furnished to the editor by Professor Matteucci, and containing a very large number of additions and corrections. The numerous errors of the French edition,—so far as matter is concerned more complete than the Italian ones,—have been corrected by the author in the present translation, and he has also embodied in it the results of his more recent investigations. A few notes and some additional wood cuts have been appended by the editor, Dr. Pereira. In compliance with the request of Professor Matteucci, the work is most appropriately inscribed to Dr. Faraday, "to whom," as the editor justly observes, "the physical sciences are indebted for some of the most brilliant and splendid discoveries of this prolific age."

Lecture I. is introductory and treats of generalities.

> "It is perhaps the first time," says Prof. Matteucci, "that a course of lectures, under this name, has been introduced into medico-physical education. We have no work which treats exclusively of this subject: the germs, indeed, are scattered here and there, but hitherto they have never been viewed in the light most favourable to their development." (p. 2.)

Living beings are endowed with the general properties of all natural bodies. Living organized matter is extended, impenetrable, divisible, and porous. How can we believe that caloric, electricity, light, and chemical affinity, act on these beings in a manner entirely different from that which they are known to do on the other bodies of nature? Many of the differences between, and even of the presumed opposite characters of, organic and inorganic bodies, found in the works on Physiology, have little or no value.

> "Animals and vegetables grow by intussusception, minerals by juxtaposition;—in other words, in the former, growth takes place by internal juxtaposition, in the latter by external juxtaposition; for organized bodies conceal in their interior the

dissolved elements of new formations, whilst, on the contrary, these elements are situated externally in the case of inorganic bodies."—(p. 3.)

All the phenomena of living beings are, however, not explicable by reference to physical and chemical forces merely; and even *the most physical, the most chemical* phenomena of living beings exhibit considerable differences in the mode of action of physical and chemical agents in the organism, and which are as yet inexplicable by our knowledge of the laws governing these forces—as, for example, the peculiarities of vision, a purely physical phenomenon; for, how, by the aid of physical laws, can we explain the perception of a single object in its natural position, by a double and inverted image?

"The chemical action of light, which decomposes carbonic acid, carries the carbon under the form of new combinations into the interior of vegetables, disengages the oxygen, and thus produces what the most powerful chemical affinities cannot accomplish, is certainly different from that which decomposes some oxides and metallic chlorides, an effect for the production of which the feeblest chemical actions are sufficient. Apply an electric current to the nerves of a living animal, and the peculiarity of the resulting phenomena will prove to you the immense difference which exists between the effects of the great forces of nature, according as the body in which they occur is living and organized, or inorganic and dead." —(pp. 7, 8.)

What, then, is the cause of these extraordinary differences in the modes of action of physical agents on living beings and on other bodies of nature? This primary question of the highest importance, is one to which, in the existing state of our knowledge, no satisfactory reply can be given. We can only conclude that the fact of organization, and the molecular structure of living beings effect important modifications in the action of physical and chemical agents. Every day, however, adds to the number of those chemical phenomena, what are inexplicable by the ordinary laws of affinity alone—the *actions of contact or catalysis.* To this category of phenomena belong the various kinds of fermentation. And the number of catalytic actions in living beings is immense. The whole mechanism of cell-life is explained by aid of the phenomenon of endosmose alone, effected entirely under the dominion of physical forces. But, while we thus properly conclude, that living beings have the general properties of all the bodies of nature, and that these properties are influential in the production of the phenomena proper to them; that the great physical agents, caloric, light, electricity, and molecular attraction, act on living beings as well as on all the bodies of nature, and that their action must necessarily be influential in the peculiar functions of these beings; and that the general mode of action of these forces is often modified, when acting on organized matter, owing to a difference in its structure and chemical composition;—we must still admit in living beings phenomena, numerous and highly important, which we call vital, and that we are unable to explain how their production can be influenced by physical agents.

With these preliminary remarks, we shall proceed to *Lecture II.*, which is devoted to the consideration of *molecular attraction, capillary forces, and imbibition.* To comprehend the phenomena of absorption and exhalation, it is necessary to understand the purely physical phenomena of capillarity and imbibition, on account of their agency in these functions. When a body is plunged into a liquid, the latter is either elevated or depressed around the solid, and presents, at its point of contact with it, a concave, or a convex surface, according as it is either elevated or depressed. In the first case, the body is moistened, as glass when introduced into water; in the second, the body does not become wetted, as when the glass is immersed in mercury. When two bodies, sufficiently near to each other, are plunged into a liquid, the latter is either elevated or depressed, according as they are, or are not moistened by the liquid. If we plunge into a liquid, a glass tube open at both extremities, the liquid rises or falls into the tube, and the effect is greater in proportion to the smallness of the bore of the tube. It is twice as great as between the glass plates. In a tube of 1 millimetre (about $\frac{1}{25}$ of an inch) in diameter, the water rises 30 millimetres (about $1\frac{1}{5}$ inches). It will readily be admitted, that capillary actions must exercise great influence over the functions of the tissues of animals and vegetables, when we reflect that the interstices and the capillary tubes of the tissues have a diameter of from $\frac{1}{100}$ to $\frac{1}{200}$ of a millimetre, (about the $\frac{1}{2540}$ to about $\frac{1}{5080}$ of an inch). The concave surface of the elevated liquid, and the convexity of the depressed liquid, belong to a hemisphere whose diameter is equal to that of the tube. The phenomena in question are entirely independent of the volume of the solid body, and consequently the thickness of the walls of the capillary tube are without influence on them. They occur equally in air at the ordinary pressure, in condensed or rarified air, in a vacuum, and in any gaseous medium. But it is in proportion to the temperature of the liquid, and in a greater ratio than that of the diminished density produced by the heat. These elevations and depressions are independent of the density of the liquids. Thus, if we represent by 100, the elevation of water in a tube, that of alcohol will be 40, that of the volatile oil of lavender 37, and that of a saturated solution of common salt, 88. It should be remembered, too, that whatever be the height to which a liquid rises, it never overflows the upper opening of the capillary tube; for the surface of the column of liquid is always concave outwardly. These phenomena depend on that force which is called molecular attraction—a force which is exerted between the molecules of the solid and those of the liquid, and between those of the liquid itself, and which ceases to act as soon as the smallest appreciable intervals separate the molecules. It must be borne in mind that a space completely filled with liquid is incapable of exercising any capillary influence; that the action of a capillary tube on liquids is due, less to the substance of the tube, than to the nature of the liquid with which its inner surface is moistened, and finally that liquids never overflow the upper aperture of the tubes in which they are elevated by the mere agency of capillarity.

The phenomena of imbibition are the same as those of capillary action, and deserve to be more attentively studied than they have yet been. The following are the results of some of the experiments which Professor Matteucci, in conjunction with Professor Cima, made on this subject. They carefully filled six tubes of glass of two centimetres (about $\frac{4}{5}$ths of an inch) with finely-sifted and well-dried very white sand. The ends to be immersed were covered with cloth, and the tubes were then plunged at the same moment into six different liquids, at a temperature of + 12° centig., (= 53° 6′ Fahr.), to the depth of about $\frac{1}{2}$ centimetre (about $\frac{1}{5}$th of an inch); and in order that this depth should be constant, more liquid was from time to time added. The action of imbibition, by which the liquids were elevated in the tubes, was continued for ten hours; at first being rapid, but gradually becoming slower until it ultimately ceased.

"The following are the greatest heights to which the different liquids rose. All the saline solutions were of the same density, viz. 10° of Baumé's areometer [sp. gr. 1·075].

Solution of carbonate of potash	85 Mill.
Solution of sulphate of copper	75
Serum of blood	70
Solution of carbonate of ammonia	62
Distilled water	60
Solution of common salt	58
White of egg, diluted with its own volume of water	35
Milk	55

This table shows how much imbibition differs in the case of different liquids: in solutions thickened with gum, with boiled starch or with oil, scarcely any imbibition takes place; and it is also very feeble in concentrated saline solutions and in all liquids holding very finely divided particles of solid matter in suspension: in the latter case it effects a kind of filtration. This phenomenon of imbibition may, in the case of solutions holding in suspension very finely divided molecules of solid matter, be very valuable for ascertaining the different properties of the blood according to its density. In fact, in certain maladies, its density and its viscidity are much diminished; and in these cases serous infiltrations take place as they do also, for the same reasons, after profuse sanguineous discharges. We shall hereafter find that alcohol, ether, water, &c., as well as aqueous solutions, when introduced into the stomach of living animals, disappear, but in unequal intervals of time, oil remaining there for a very long period.

"Believing that it would be of importance to compare alcohol at 36° Baumé [sp. gr. 0·844] with distilled water, I provided myself with tubes filled with sand, pounded glass and sawdust, and here are the elevations that I obtained.

Tube with Sand.	Tube with pounded Glass.	Tube with Sawdust.
Alcohol, 85 millim.	175 millim.	125 millim.
Water, 175 —	182 —	60 —

"Thus we see clearly that with either sand or pounded glass alcohol rises less than water; a fact which is in accordance with that which happens with capillary tubes.

"In another experiment I plunged into the same liquid, namely, water, two tubes both holding pounded glass, but the one containing twice as much as the other; consequently the powder was finer in the first tube. The following were the results obtained:—

"In the first tube the liquid rose to 170 millimetres, in the second to 107 millimetres only in the same period."—(pp. 22–24)

The influence of temperature on imbibition is very considerable.

"Two tubes prepared with sand were plunged into water, the one at a temperature of + 55° centig. [= 131° F.], the other at + 15° centig. [= 59° F.], and the results obtained were as follow:—

	Elevation after 70 seconds.	Elevation after 11 minutes.
Tube at + 55° centig.	10 millim.	175 millim.
at + 15 —	6 —	12 —

The important part that imbibition plays in the action of the juices of plants, as well as in the phenomena of the capillary circulation of the blood in animals, is mentioned and illustrated by reference to the experiments of Hales, and the more recent ones of Boucherie. The latter saw a poplar nearly ninety-two feet in height, absorb, by its trunk, in six days, the enormous quantity of sixty-six imperial gallons of a solution of pyrolignite of iron.

The following experiments were made with the view of producing by the mere operation of capillary forces and molecular attraction the effects of chemical affinity.

> "If we reflect that any kind of liquid constantly ascends to the same height in a capillary tube; that during imbibition more or less heat is produced, as the experiments of Pouillet have demonstrated; that, moreover, according to Becquerel, there is a disengagement of electricity; and, lastly, that capillary attraction is exerted at very minute distances only, and between the molecules of bodies; we cannot deny that this force combines the principal characters of chemical affinity. We know the experiment of Doebeireiner, that if a mixture of water and alcohol contained in a bladder be exposed to the air, water constantly escapes from the mixture. In this case the water is imbibed by the membrane more readily than the alcohol, and is dissipated by evaporation.
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> "Another and more conclusive fact is mentioned by Berzelius; a saline solution filtering through a long tube filled with sand runs out more or less, completely deprived of salt. I have confirmed this experiment by using a tube of about 8 metres [about 26 feet] long, filled with sand, and I have found that the density of the liquid, introduced by the upper aperture of the tube, was to that of the liquid escaping from the other end, as 1 : 0·91. But it is necessary to state that this difference of density was not always maintained; after a certain time, the saline solution is as dense at its exit from the tube as at its entrance. This proves that the decomposition of the saline solution takes place in the first action of contact between it and the particles of sand.
>
> "I have obtained an inverse result by employing a solution of carbonate of soda, which I caused to pass through a tube 3 metres [nearly 10 feet] long, filled with sand. The density of the liquid at its exit was to that at its entrance as 1·005 : 1.
>
> "The phenomena we have just referred to are very important on account of the applications that can be made of them to some of the functions of living beings which are not completely explicable by the mere action of capillarity and molecular attraction."—(Pp. 30-32.)

Lecture III. treats of *endosmose*, a phenomenon which, though exclusively within the domain of physics, is, nevertheless, intimately connected with the study of organized beings, by the physiological applications of which it is susceptible.*

Dutrochet, and Poisson, and Becquerel, have endeavoured to give an explanation of the phenomena of endosmose, but Professor Matteucci remarks, that

> "Up to the present time we have not any satisfactory theory of endosmose; but we know that the general conditions of the phenomena are as follow:—1st. That the two liquids should have an affinity for the interposed membrane. 2dly. That the two liquids should have an affinity for each other, and be miscible. If one of these conditions be wanting, endosmose does not take place. Experiment proves that the current of endosmose is not produced by the least dense liquids, nor by the most viscid one, nor by that which is endowed with the greatest force of ascent in capillary tubes. The current is in general determined by the liquid which has the greatest affinity for the interposed substance, and by which it is imbibed with the greatest rapidity. In fact it is evident that the membrane im-

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* Dr. Pereira, in a note, claims priority for both Mr. Porrett, of London, and M. Parot, of St. Petersburgh, in the discovery of the phenomenon of Endosmose. Dutrochet's first memoir was read to the *Académie Royale des Sciences*, on the 23d of July, 1827, whilst Mr. Porrett had communicated to the editor of the *Annals of Philosophy* (vol. viii., July, 1816), a paper on two "*curious galvanic experiments*," one of which was the production of endosmose between two liquids separated by a membrane, and subjected to the action of voltaic electricity. He called the phenomenon *electro-filtration*; and asks, whether jointly with electro-chemical action, it is not "in constant operation in the minute pores and vessels of the animal system." In 1844, M. Parot communicated to the *Académie Royale des Sciences*, an inaugural dissertation, published in 1803, giving an account of the phenomena presented by two liquids of unequal density, separated by a permeable organic diaphragm, and pointing out their application to physiology and pathology.

bibes the two liquids unequally; and that the one which is imbibed with the greatest facility, ought to mix with, and augment the volume of the other."—(p. 39.)

Dutrochet found that the slightest trace of sulphuretted hydrogen destroyed endosmose; but Matteucci thinks, however, that this effect arises from the alteration of the structure of the membrane when it commences to evolve gas; for he found fresh membrane placed in contact with sulphuretted hydrogen to be very active. Dutrochet endeavoured to measure the velocity with which a liquid passes, by virtue of endosmose, from the exterior to the interior of the endosmometer; and it was made evident that the velocity of endosmose is proportional to the excess of density of the interior liquid, over that of the water employed as the exterior liquid. Among the curious facts discovered by Dutrochet, was that of the variation in the direction of the current between certain acid solutions and water, according to their density and temperature.

"This is especially manifested by a solution of hydrochloric acid. Thus, with hydrochloric acid at the density of 1·02, endosmose takes place from the water to the acid, whilst at the density of 1·015, the current is in the opposite direction; that is to say, it is from the acid to the water."—(p. 37.)

The phenomenon of endosmose is perhaps one of the most important physical facts applicable to the functions of living beings; yet hitherto very few investigations have been undertaken with the view of connecting it with physiology.

"To do this it was necessary to vary the liquids between which endosmose takes place, and to select the membranes, so that we might always keep as close as possible to the conditions under which the analogies between this phenomenon and those which exist in the interior of living bodies, have been observed."—(p. 41.)

To effect this inquiry, Professors Matteucci and Cima undertook a number of experiments, the results of which are highly interesting and important. The membranes which were submitted to experiment were, 1st, the skin of the frog, the torpedo, and the eel; 2d, the stomach of the lamb, the cat and the dog, and the gizzard of the fowl; and 3d, the bladder of the ox, and of the pig. The first series comprehended the experiments with the cutaneous membrane, and it was in these that the marked influence exercised upon the phenomenon of endosmose by the position of the interposed membrane, was first noticed.

"By employing the skin of the torpedo, placed in one endosmometer with its external surface towards the interior of the instrument, and in the other reversely, and by filling the two endosmometers with a solution of gum Arabic, we observed that, whilst the liquid in the first instrument rose 30 millimetres, it rose in the second sometimes 18, and sometimes only 6 millimetres. In certain cases we saw the liquid elevated 20 millimetres or more, in the first tube, whilst it scarcely rose at all in the second.

"These differences are equally observed with a solution of sugar. Thus, this liquid which rises 30 and even 80 millimetres when the external surface of the skin is turned towards the instrument where the liquid is contained, rises at the utmost only 2 millimetres when the membrane is placed in the contrary direction. In one case where the first-named arrangement was adopted, the liquid rose 80 millimetres; but reached only 30 millimetres when the second arrangement was resorted to.

"With albuminous solutions the elevation was 26 millimetres when the external surface of the skin was in contact with it, and 13 millimetres when placed in the contrary direction."—(pp. 44, 45.)

The results obtained with the skin of the frog agreed in general with those furnished by the skin of the torpedo. In the case of the eel-skin, the elevation of the liquid was for a time alike, whichever side of the membrane was turned towards the solution of sugar; but after a lapse of two hours, in the endosmometer in which the external surface of the skin was in contact with the solution of sugar, the elevation was 30 millimetres, while in the other instrument it was only 20 millimetres. With a solution of albumen or gum water, the differences were observed from the commencement.

> "By employing water and alcohol, Dutrochet obtained the current in the direction from the former to the latter. This consequently formed an exception to all the other cases, in which he found that the direction of the current was from the least to the most dense liquid. The influence of the position of the skin, employed as the membrane interposed between these two liquids, has been rendered evident by our experiments; but the position favourable to the current, which is constantly from the water towards the alcohol, is not the same for the three kinds of skins alluded to. Thus, when we use the skin of the frog, the current is promoted from the external to the internal surface, by being directed always from the water to the alcohol. In various and frequently repeated experiments, we have observed an elevation of 20, 24, and 40 millimetres when the internal surface of the skin was placed towards the alcohol, whilst in the reverse position the corresponding elevations were only 4, 12, and 20 millimetres. Under analogous circumstances, the position of the membrane being favourable, the elevation was 28 millimetres; in the other position, on the contrary, there was no elevation. With the skin of the eel the reverse takes place. With this the current is favoured from the internal to the external surface: and whilst the alcohol contained in the instrument rises to the height of 20 millimetres, when in contact with the external surface of the skin, it only rises to 10 millimetres when the position is reversed. This difference of elevation always takes place in the same direction, and is confirmed for the eel-skin, as for the skin of the torpedo. The elevation has been at 50 millimetres in one instrument, and 20 in the other."—(pp. 47, 48.)

In the second series, the mucous membrane of the stomach of the lamb, the dog, and the cat, and the gizzard of the fowl was employed. The stomachs were taken from these animals immediately after death. The cutaneous membranes exhibited similar differences. When alcohol was employed for the inner liquid, and put successively in contact with each of the surfaces of these membranes, the differences were most remarkable.

> "With the stomachs of the lamb, the cat, and the dog, endosmose was invariably directed from the water to alcohol, and was promoted from the internal to the external surface of the membrane. Indeed, we have seen in the endosmometer where the external surface of the mucous membrane of the stomach of the lamb was turned towards the interior of the instrument which contained alcohol, the elevation attained 88 millimetres, and only 10 millimetres in the contrary position; afterwards the liquid in the first endosmometer rose 40 other millimetres, and remained stationary, and sometimes even fell in the second instrument.
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> "With the stomach of the cat, alcohol rose 22 millimetres in the tube in two hours, when the external surface of the membrane was turned towards the interior of the endosmometer, but with a contrary arrangement it did not rise more than 2 millimetres. Sometimes even when, in the first position of the membrane, the elevation was from 20 to 24 millimetres, in the second there was no elevation. With the stomach of the dog, the elevation of alcohol in the tube was 24 millimetres when the mucous surface was in contact with water, but was only 16 millimetres when placed in the reverse position. Six hours after, the liquid rose again 40 other millimetres in the first case, and 25 millimetres only in the second one. In another experiment, after the time mentioned, the elevations were 130 millimetres and 6 millimetres. With the stomachs which we have hitherto employed, endosmose, which is promoted from the internal to the external surface of the membrane, always takes place from water to alcohol, as in Dutrochet's experiments. It is remarkable that, with the internal membrane of the gizzard of

the fowl, endosmose takes place in the contrary way, namely, from alcohol to water; and this holds good whatever be the position of the membrane with respect to the two liquids. This exception, which we at first attributed to some defect in the membrane employed, we have repeatedly verified, sometimes by introducing, as usual, the alcohol into the interior of the instrument, in which case we have seen the alcohol fall below the level, and sometimes by placing it externally, when the water constantly mounted in the tube. The influence of the position of the membrane is equally evident in this case. We shall commence by giving the diminutions of height marked in the case where the alcohol was in the interior of the instrument. When the internal surface of the mucous membrane was towards the interior of the endosmometer, the diminution of the height of the alcohol was from 24 to 28, and even more than this, in the space of six hours, whilst it was only 11 and 12 millimetres in the other position. In another experiment, which we have selected out of a very large number, the pure water being placed in the interior of the instrument, the elevation was 32 millimetres when the external surface of the membrane was towards the interior of the endosmometer, and 16 millimetres in the other position, in about the space of three hours. Consequently endosmose between alcohol is promoted from the internal surface to the external surface of the gizzard of the fowl."—(pp. 58, 59, 60)

In the third series the mucous membrane of the bladder of the ox, in a fresh state, was employed. The height which a solution of sugar attained

"Was, when the internal surface of the membrane was in contact with the saccharine liquid, 80, and even 113, millimetres in the space of two hours; but it was only 63, or 72, millimetres when the position of the membrane was reversed. The current of endosmose, therefore, is promoted in this instance from the external to the internal surface of the membrane. The contrary effect is obtained with a solution of gum Arabic. The elevation is 18, and sometimes only 7, millimetres, when the internal surface is turned towards the interior of the instrument containing the gum solution; whereas, when the membrane is arranged the reverse way, the elevation is 52 millimetres, or, in some cases, 20 millimetres."—(p. 61.)

With the gummy solution, the liquid sometimes first fell in both tubes, and after some time, rose to nearly the same heights as those observed with the saccharine liquid. With an albuminous solution and pure water, no endosmose took place; the liquid falling in both tubes, whether the interior of the instrument contained the albuminous solution or pure water.

"Yet it should be mentioned, that when the inner surface of the membrane is in contact with the albuminous solution placed outside the instrument, the diminution of height is less than when the position is reversed; and that the contrary takes place when this solution is in contact with the external surface of the membrane. Lastly, with alcohol and pure water there is endosmose from the water to the alcohol, as in most cases; but the elevation is sometimes 24 millimetres, sometimes 59 millimetres, when the external surface of the membrane is in contact with the alcohol, and sometimes 26, or 37, millimetres in the reverse arrangement."—(pp. 61, 62.)

These phenomena were all more or less modified when the membrane used had undergone more or less the putrefactive process; thus demonstrating the intimate relation existing between the phenomenon of endosmose and the physiological condition of the membranes.

"The phenomenon of endosmose, like everything going on in organized tissues, is devoid of that constancy and regularity observed in physical phenomena elsewhere. To this variable and accidental organic condition of the fresh membranes must be ascribed the singular fact, that while in certain cases we obtain an elevation of perhaps 80 millimetres, yet sometimes with the same liquid, the same membrane, and in the same relative position, the rise does not exceed 10 millimetres. We must also ascribe to a constant anatomico-physiological condition, connected with the function of the same membrane, that constant difference of elevation in the two different positions of the membrane, whatever this difference may in other respects be. It is important to study the phenomenon with the view of recognizing the accidental circumstances which cause the variation of endosmose through the fresh membranes; as, for example, the privation of nourishment in relation to the stomach, the administration of certain substances to the animal before killing it, &c."—(p. 64–65.)

On the subject of *exosmose*, Professor Matteucci observes :—

"That in ascribing everything to endosmose, the presence of the solution of gum, or of sugar, in the interior of the endosmometer, gives us no explanation of the phenomena which are observed with the internal membrane of the stomach of the lamb, and with the mucous membrane of the bladder of the ox; and that these phenomena are susceptible of a more easy and natural explanation, by assuming that, by exosmose, the various membranes give to the different liquids a more or less easy passage towards the water, according to the surface with which these liquids are in contact; and by supposing that the passage of the water towards the denser liquid is always constant, in accordance with the almost general law of endosmose."—(p. 67.)

But to ascertain the correctness of these views, it was necessary to resort to experiment, and not only to prove the existence of exosmose, but also, to measure it in the same manner as exosmose. A number of interesting experiments were undertaken, and their results are given. When equal volumes of salt water of known density was introduced in two endosmometers, in one of which the internal surface of the skin of the eel or frog was placed towards the interior of the vessel, and in the other, was in the contrary position, were plunged into two vessels of distilled water of the same volume as the salt water, it was

"Observed that endosmose from water to a saline solution through these skins, was most promoted from the internal to the external surface. By determining the density of the liquids contained in the two vessels, we found that in the endosmometer, *in which the volume of salt water was most increased, the density of the liquid was preserved better than in the other;* and vice versâ, *in the vessel in which the diminution of distilled water was greatest, the quantity of the saline solution introduced by exosmose was less than in the other vessel from which a smaller volume of distilled water had disappeared.*"—(p. 68.)

A similar result was observed with the solution of sugar and the skin of the eel.

"These facts cannot be explained by assuming that the elevation and increase of volume of the liquid of the two endosmometers arise merely from the difference between the current of endosmose and that of exosmose. If it were so, the endosmometer in which the largest quantity of saline solution had accumulated, ought to contain a liquid less dense than that in the other which presented a less augmentation of volume. These facts may be, on the contrary, completely explained, by assuming that the current of endosmose has been equal, or nearly so, in the two positions of the membrane, and that the difference depends altogether in the current of exosmose, which is weakest in that endosmometer in which the elevation is most considerable, and stronger in the one in which the elevation is the slightest. These results give a great importance to the influence of the membrane interposed between the two liquids in the phenomenon of endosmose; for, by its particular nature alone and its physiological function, we can explain the more or less easy passage of different denser liquids towards other less dense ones through the membrane itself."—(pp. 70, 71.)

In all the skins experimented on, the exosmose of solutions of sugar, albumen and gum, towards water, is promoted from the internal to the external surface.

"It is precisely in this same direction through the skin of the torpedo, the eel,

> the frog, and other animals, that a copious secretion of mucus takes place. The endosmose of water to a solution of sugar, of gum, and of albumen, is less intense from the external to the internal surface of the skin than when it takes place by the reverse arrangement. Consequently, if we do not admit that this secretion of mucus, and this weak absorption of the water wherein these animals live (functions which, for their normal performance, ought always to bear a certain relation to each other), are entirely due to the phenomena we have discovered; at all events, we cannot deny that they must be promoted by it. Undoubtedly this function of the skin would not go on, or would do so imperfectly, if in these animals which live constantly in water, this membrane acted endosmotically in an opposite direction to that which we have found it to do.
>
> "This constancy observed in the direction most favourable for endosmose and exosmose through skins, does not hold good for the mucous membrane of the stomach of different animals. But every one knows how much more complicated the function of the stomach is, and that all the substances introduced into this organ are either not absorbed, or are absorbed unequally. Moreover, we repeat, that this subject requires elucidation by fresh experiments. When we remark that the direction most favourable to endosmose between water and a saccharine solution, for example, is not the same for the stomach of a ruminant as for the stomach of a carnivorous animal; it clearly follows that the phenomenon of endosmose must be intimately connected with the great differences which exist in the digestive functions of these two orders of animals."—(pp. 71, 72.)

The recent experiments of Poiseuille, made with the view of explaining by endosmose the purgative action of certain saline substances, are next referred to. He found that there was endosmose through animal tissues from the serum of the blood to Seidlitz water, and to solutions of the sulphate of soda and common salt. Now this is precisely what happens on the internal administration of these medicines; the excrements contain a large amount of albumen; and we must admit, that endosmose takes place through the capillary vessels of the intestine, from the serum of the blood to the saline solution introduced into the alimentary canal. To substantiate Poiseuille's views, it was necessary to demonstrate that endosmose occurs when one of the liquids is in motion, and is being continually renewed. This has been done by Dr. Bacchetti, who has shown that the rapidity of endosmose is considerably augmented when one of the liquids was constantly renewed. This result is in accordance with the principles of the theory of endosmose; for the constant interchange of the same liquids through the membrane suspends, finally, endosmose. Poiseuille has, also, shown that endosmose ceases to take place in a membrane after a certain time of action; but that the membrane reacquires this property, by submitting it to the action of other liquids.

The influence exercised on endosmose, by the hydrochlorate of morphia, is another remarkable and valuable fact, for which we are indebted to Poiseuille and Bachetti. This salt, when added to saline solutions, weakens considerably the endosmose from the serum to the solution, and ultimately changes the direction of the current.

> "How," inquires Professor Matteucci, "can we make an entire abstraction of this fact in the explanation of the action of morphia, and of the preparations of opium in diarrhœa, as well as of the constipation which they produce?"—(p. 74.)

Lecture IV.—*Absorption* and *exhalation* in animals and plants are considered, the preceding lectures on the phenomena of capillarity, imbibition, and endosmose, having prepared the way for their study. Absorption in animals, consists of two acts—imbibition and transmission; the substance to be absorbed is not only to be introduced through the interstices of an organized body, but it is to pass into the circulation, the final object of the phenomenon. If a frog, whose inferior extremities only have been immersed in a solution of ferrocyanide of potassium, be, after careful washing, cut in pieces, by touching any part with a glass rod, moistened with muriated tincture of iron, a blue stain is produced, proving that the solution has penetrated every part. If a living frog be treated in the same way and then killed, scarcely any traces of the salt can be detected in the muscles of the legs and thighs (the immersed parts), whilst the heart and lungs give distinct evidence of its presence.

> "One experiment more, and the conclusion will be evident. I immerse another frog, which has been dead for some minutes, in the same solution, and leave it there for the same time that I did the other. When tested, the lungs and heart offer no greater evidences of the presence of the ferrocyanide than does any other part of the body. Here is the explanation of these experiments:—The solution was introduced into the body of the frog simply by imbibition; and this phenomenon, being effected in the living as well as in the dead frog, certainly cannot be regarded as different from the imbibition which we have already studied, which belongs to both organic and inorganic bodies, and which is the consequence of their cellular and vascular structure, &c. But there is something more than this. In the heart and lungs of a living frog we find a much larger quantity of the absorbed solution than in the other parts of the body, although these latter were much nearer the part immersed. These viscera are the centre of the circulatory system: in them commence or terminate the trunks of the blood-vessels. The solution of the ferrocyanide, therefore, has penetrated the blood-vessels by imbibition, mingled with the blood, and thus arrived at the heart and lungs. We have another very simple experiment proving the same facts:—I take two frogs, and from one remove the heart; the animals are equally lively. Both are placed in a large glass containing a solution of the extract of nux vomica. The animal with the heart is soon poisoned, and long before the other becomes affected."—(pp. 77, 78.)

All vessels absorb; the lymphatics as well as the blood-vessels. That absorption is a physical phenomenon, is not only shown by the conditions under which it takes place, but also by positive experiment. Take a long piece of vein from any large animal, and attach it at one end to a tube in the lower part of the side of a glass bottle filled with water, and tie the other extremity to a small bent glass tube, furnished with a stop-cock; immerse a portion of the vein in water, accidulated with sulphuric or hydrochloric acid. At first the liquid within the bottle gives no indication of the presence of the acid; but if the stop-cock be opened, the liquid which flows out through the veins is acid. After some time the fluid in the bottle is found also to be acidulated. If a tube of clay or of pasteboard, or of wood be substituted, the same happens. If the acidulated solution be contained in the interior of the vein; and if litmus be added to pure water in the basin, the same phenomenon is observed; and the acid will pass out through the coats of the vein, with a facility proportionate to the velocity of the current.

> "Suppose for a moment that the direction of the circulation of the blood was inverse to that which it really is, but without any alteration in the structure and disposition of the blood-vessels; we should then no longer say that the veins absorbed, but, on the contrary, that absorption took place by the arteries. Such is the very simple physical phenomenon of this function."—(p. 83.)

The laws of absorption are next very happily illustrated by the application of the principles previously laid down.

The function of *exhalation* is, in general, effected by the same mechanism, and under the same laws as those of absorption. In every vessel capable of imbibition, a portion of the contained liquid is constantly passing out or *exhaling* through its coats, in proportion to the greater or less facility with which it is imbibed by the tissue of the vessel, and the greater or less moisture of the sides of the vessel. The exhalation will be augmented if, in consequence of the very large quantity of contained liquid, the walls of the vessel are subjected to increased pressure. Edwards has proved, that cutaneous exhalation is, in some cases, ten times greater in dry than in moist air, and that it is doubled in passing from 32° Fahr. to 68°. He also found that transpiration was augmented by agitating the air around the body of an animal.

"Some of the phenomena of absorption and exhalation in living beings, are accomplished by the transformation of absorbed or exhaled body. The liquid which is imbibed by a membrane, and exhaled from its opposite surface, is not identical with that which was placed in contact with the absorbing membrane. This happens in most of the cases of exhalation, and principally in the secretions. We are very far from expecting to find, in the present condition of physico-chemical knowledge, an explanation of the phenomena of the secretions. We must admit that they form as yet one of the most obscure subjects of the animal economy. With respect to exhalation it may be observed, that in some cases it is effected by a kind of filtration. A liquid which contains in suspension insoluble particles, is separated by filtration into two portions: the liquid part, which is imbibed by the substance of the filter, and is strained; and the solid part, which remains on the filter. Anatomists know that by injecting into the veins or arteries a solution of gelatine coloured by very finely powdered vermilion, the solution becomes colourless when it percolates through the coats of the vessels. Every contusion of the skin produces a spot, the centre of which is of a dark blue, and the circumference of a green colour surrounded by yellow. In this case, the extravasated clot of blood is separated from the serum, which is imbibed by the neighbouring tissues. Do not forget the fact which has been demonstrated to you respecting imbibition. Salt water becomes fresh by traversing a bed of sand; while a solution of carbonate of soda, filtered under the same conditions, becomes denser. Imbibition, capillarity, and the simple play of molecular attraction, can overcome affinities. The old notion, therefore, according to which the secreting organs were considered as mere filtering apparatus, is not entirely without foundation."—(pp. 88, 90.)

The lecture concludes with a sketch of absorption in plants. Prof. Matteucci admits that the movement of the juices of plants is inexplicable by capillarity and imbibition merely.

"The cause resides principally in the roots, and in the next place in the leaves. It is probable that an action of endosmose occurs in the extremity of the roots; and it is not unnatural to suppose that a similar cause acts in the movements of the chyle and lymph in the lymphatic and chyliferous vessels; a movement which continues some time after death."—(p. 96.)

Lecture V. treats of Digestion; it is an able summary of that subject, and contains some original researches of the author on the *absorption of fat.*

"It is difficult to determine precisely by analogies derived from chemistry, what becomes of the fatty substances after they have passed out of the stomach. It is certain that they are there absorbed, and that the chyliferous vessels may be considered as almost exclusively charged with this function. Here are some experiments, by means of which I have endeavoured to diminish the obscurity which hangs over this part of the digestive process. I put into a mattrass a solution of 300 grammes [= 9 oz. 132 grs. troy] of distilled water, $1\frac{3}{10}$ grammes [about 20 grains troy] of caustic potash. This solution has not any perceptible alkaline taste, and acts very feebly on litmus paper; it is a liquid whose alkalinity is about equal to that of the lymph and chyle. By means of a salt water bath, I expose the mattrass to a temperature of from 35° to 40° centig. [= 95° to 104° Fahr.]; I then add some drops of olive oil and shake the mixture: it instantly becomes so milky that it might be mistaken for milk itself. The liquid thus obtained, when left to itself, preserves its analogy to milk, and separates into two layers, the one more opaque at the top, in which are evidently small globules of fatty matter; the other, below, and less opaque, although still having a milky aspect. I have filled a piece of intestine with this species of emulsion, and plunged it into the alkaline solution already described, whose temperature was maintained at from + 35° to 40° centig. [= 95° to 104° Fahr.] After some time the latter becomes turbid, and acquires the characters of the interior emulsion. We, therefore, presume, that a portion of the emulsion has passed through the membrane and become diffused externally. I may mention to you another experiment which appears to me still more conclusive. I filled an endosmometer with a very weak alkaline solution, and plunged it into the emulsion. The membrane employed was, as usual, ox bladder, and the two liquids were at the temperature of + 30° centig. at the commencement of the experiment. Endosmose took place; the emulsion passed into the alkaline solution; and the liquid rose in the tube to the height of 30 millimeters in a very short time. These physical phenomena, which, although they do not explain all the peculiarities of the digestion of fatty substances, nevertheless contribute to render them less obscure. The chyliferous vessels, which terminate in closed or blind extremities (*en cul-de-sac*), and are enveloped by intestinal mucus, are, especially in a fasting animal, filled with an alkaline liquid, very analogous to lymph. After digestion, particularly when the animal has been fed on fatty substances, the liquid of the chyliferous vessels differs from what it was previously, merely by the addition of fatty corpuscles, which give it the milky appearance. It is natural to suppose, that this chemical affinity, which produces the milky liquid in the mixture of the alkaline solution and oil, is also exerted through the membrane of the chyliferous vessels, which certainly imbibes as much of the alkaline solution as of the milky liquid, formed by the action of the alkali on the fatty bodies. The phenomena of endosmose, of which I have spoken, may also be admitted, with great probability, as one of the causes which produce absorption by the chyliferous vessels. It is certain, that absorption could not take place, if the inner sides of the intestines were not bathed with some liquid, for which the fatty bodies had some affinity. It is easy to demonstrate, by experiments, that the alkaline condition of the intestinal coats favours this absorption. Fill two funnels with sand, equally shaken down in each. Pour into one, pure water, into the other, an alkaline solution; when the liquids have filtered through, pour an equal quantity of oil on each filter. For several hours the oil will remain upon the surface of the sand, which has been moistened with pure water; whilst in the other funnel, in which the sand has been moistened with the alkaline solution, the oil will rapidly disappear by imbibition. The neutral azotized substances which pass into the blood, after having been dissolved by the gastric juice, would rapidly destroy the neutral or slightly alkaline condition necessary to the preservation of the qualities of the blood; but the alkali of the chyle, of the lymph, of the bile, and of the pancreatic fluid, preserve the neutrality of it."—(pp. 111, 112, 113.)

Lectures VI. and VII., devoted to the consideration of *respiration*, *sanguification*, *nutrition*, and *animal heat*, contain much that is interesting and important, though but few original observations, and need not, therefore, detain us, as our object is chiefly to present to the reader the original researches of Prof. Matteucci himself.

Lecture VIII., on the Phosphorescence of Organized Beings, contains some highly interesting observations on the *Lampyris Italica* or *Italian glow-worm*, the last two segments of whose body, which by day appear yellowish, are slightly luminous in the dusk, and during the night evolve a bright intermittent light. This yellowish matter continues to emit light when separated from the body of the animal. The following are some of the conclusions which Prof. Matteucci arrived at in studying the phosphorescence of the glow-worm.

"1st. The phosphorescence of the glow-worm may cease, without the insect being dead.

"2d. There exists in this insect a matter which evolves light, without any appreciable heat; and the animal to manifest this property, does not necessarily require either to be entire, or to possess life.

"3d. Carbonic acid and hydrogen form a medium in which the phosphorescent matter of the glow-worm ceases to shine after an interval of time, not exceeding thirty or forty minutes, provided that the gases are pure.

"4th. In oxygen gas, the brilliancy of the phosphorescent matter is considerably greater than in atmospheric air, and the duration of the phosphorescence is nearly three times as long. This holds good with regard to the luminous segments only, as well as with the entire animal.

"5th. This phosphorescent matter, placed under conditions suitable for the emission of light, absorbs a portion of oxygen, which is replaced by an equal volume of carbonic acid.

"6th. This same substance, when deprived of its faculty of glowing, and then placed in contact with oxygen gas, no longer absorbs oxygen, or produces carbonic acid.

"7th. Oxygen mixed with either hydrogen or carbonic acid, in the proportion of 1 to 9, forms a medium in which the phosphorescence continues for several hours. We may, therefore, conclude, that it is in consequence of some alteration in the phosphorescent matter, that this ceases to glow after it has been for some days in pure oxygen, one portion only of which has been replaced by carbonic acid.

"I examined the hydrogen, in which I had kept several glow-worms for the space of twenty-four hours, and in which they had glowed for a few minutes only. The following is the result obtained when the gas was pure, and the experiment was conducted over mercury; the bell-glass being carefully filled by inverting it two or three times, in order to get rid of all the air adhering to the glow-worms: the volume of the gas was slightly augmented: with 8 cubic centimetres of hydrogen, I obtained an excess of 0·2 cubic centim. which was absorbed by potash. Thus, then, the insects produce carbonic acid, which must either be formed by the union of carbon with the oxygen remaining in the tracheæ, or exist ready formed in the animals. When the luminous segments alone are placed in hydrogen, with due precaution, they glow for a few seconds only and the gas is not altered.

"8th. Heat, within certain limits, augments the light of the phosphorescent matter; cold has a reverse effect.

"9th. When the heat is too strong, the phosphorescent matter becomes altered, as it also does when placed in the air or in any gas whatever for a certain length of time. This undoubtedly is the reason why these insects cannot live in all climates, and why they shine only during certain months of the year.

"10th. The phosphorescent matter, when thus altered, is no longer capable of emitting light or of becoming luminous.

"These conclusions evidently prove the nature of the phenomenon: the production of light, by this insect, is essentially connected with the combination of oxygen with carbon, which is one of the elements of the phosphorescent matter." (pp. 174, 175, 176.)

Prof. Matteucci examined the structure of the luminous organ with the microscope. He found

"On the removal of the luminous segments of the dorsal and abdominal membranes, there was perceived a yellowish, granular, globuliform matter, in which appeared groups of red globules, a great number of ramifications, and, moreover, a species of tubes which had the appearance of muscular fibre, but which, when closely examined, appeared hollow. By looking at them at night, the light was seen to be emitted by the granular yellow matter; and when we compressed this between two glasses, the light was always observed on the edges of the examined portion. The abdominal membrane examined alone, after it has been washed several times in water in order to remove from it all the phosphorescent matter, is transparent, and furnished with a great number of hairs. The dorsal membrane, less transparent than the former, is likewise hairy, but it is also supplied, on its internal surface, with many tubes or tracheæ, which penetrate the phosphorescent matter. I must further add, that I never separated the abdomen of a glow-worm without finding under the last luminous ring but one, a bright red vesicle, which, viewed by the microscope, is found to be made up of a group of red globules. I have never met with this vesicle in other insects of the same genus, and no work on comparative anatomy mentions it. In my ignorance of this science I content myself with announcing to zoologists the presence of this body."—(pp. 180, 181.)

The phosphorescent matter, taken from a living animal, has a remarkable odour, resembling that of the sweat of the feet. It is neither acid nor alkaline; dries readily in the air; appears to coagulate on contact with diluted acids; does not dissolve either in alcohol or ether, or in weak alkaline solutions.

"It dissolves and becomes changed, in hot concentrated hydrochloric and sulphuric acids. By the employment of the last-mentioned acid, the solution does not become blue, which fact excludes the idea of the presence of albumen. Heated in a tube, it gives out the usual ammoniacal products. It does not present any obvious trace of phosphorus; of this fact I have assured myself, by calcining this matter several times with nitre in a platinum crucible, and by treating the dissolved residue with the tests which indicate the presence of the phosphates. From all that we have now stated, we can no longer regard the presence of phosphorus as the cause of the light in these insects. Perhaps by operating on a large number, we might succeed in discovering a slight trace of phosphorus, which is usually found in all organized substances. From all these experiments, I conclude that carbonic acid is produced by the contact with oxygen of the phosphorescent matter alone, separated from the rest of the animal; that the light ceases to be produced when this gas is not present, and that by the contact of the latter, light and a volume of carbonic acid, equal to that of the oxygen consumed, are produced; and that the phosphorescent substance of this insect, when not luminous, does not act on oxygen. It is, therefore, natural to suppose, that in the luminous segments of these animals, enveloped by transparent membranes, and by means of the numerous tracheæ discovered here and there in these animals, atmospheric oxygen is brought in contact with a substânce, *sui generis*, principally composed of carbon, hydrogen, oxygen, and azote. The presence of a great number of dispersed blood-globules intermixed with the granular luminous matter, proves that these segments are the centre of a peculiar organ of secretion; and I believe that this red vesicle, which I have described as existing above the luminous segments, merits the attention of naturalists."—(pp. 182, 183.)

Lecture IX. treats of the *electrical current of muscles.* Prof. Matteucci, as most of our readers are no doubt aware, has devoted much zeal and labour to the investigation of animal electricity, and to the results of those investigations he owes much of his present celebrity.

Amongst the chemical actions of living beings, we have not only heat and light, but also electricity; and the existence of an electrical current is readily proved, when in connecting, by means of a conducting body, two different parts of the same muscular mass of a living or recently killed animal. The indicator or galvanoscope used by Prof. Matteucci is the leg of a frog, to which is attached the crural nerve and lumbar plexus; the muscles of the thigh having been carefully removed. The leg thus prepared is introduced into a glass tube, covered with an insulating varnish; the nervous filament projecting. With this instrument we can conduct our researches on the electric current. For, on applying one extremity of the nerve to the bottom of the wound, and another portion of the nerve to the lips of the wound, or, better still, to the external surface of the muscle, the frog's leg continually contracts; thus demonstrating the presence of an electrical current, which circulates in the nerve, since it is necessary to form a circuit, of which the nerve is a part. This phenomenon takes place in all animals warm or cold blooded. Our author has recently proved that the galvanoscopic frog exhibits the same signs when we operate on a wound made in the human muscle. If the nerve of the frog, or different portions of the muscle, be moistened with a saline or acid solution, or, still better, with an alkaline one, the contractions of the frog's leg are more energetic.

Contractions are also produced in the frog when we bring the nerve in contact with a muscle separated from the animal. The direction of the current is demonstrated to be invariably from the internal part to the surface of the muscle. To study better the fundamental laws of the electrical current, Prof. Matteucci constructed with the demi-thighs of frogs a *muscular pile*, one extremity of which was formed by the external surface of the muscle, and the other by the internal. Two cups were filled with a weak saline solution, and the two extremities of the galvanometer were plunged into them, and a deviation of the needle was immediately observed. The muscles of other animals, of fishes, birds, or mammals, may be substituted for those of the frog; and, provided that the relative position of the muscular elements be such as just indicated,—the internal surface of the muscle next to the external—more or less deviation of the needle of the galvanometer will be obtained. The intensity of the current is in proportion to the number of demi-thighs employed to form the pile. Prof. Matteucci endeavoured to ascertain whether the other tissues and organs of animals,—the membranes, the nerves, the brain, the liver, and the lungs,—denoted the presence of an electric current; but he invariably obtained very feeble signs of it. The heart alone gave indications of a very strong current. This property does not depend on the nervous system, for if the nerves which supply the muscles be destroyed, the latter do not lose their property of manifesting the electrical current. The origin of this current resides in the electric conditions, which are produced by the chemical actions of the nutrition of the muscle. The blood charged with oxygen, and the muscular fibre, which becomes transformed on contact with this liquid, compose the elements of a pile: they are the liquid acid and zinc.

> "In the normal condition of the muscle, there can only be molecular currents produced by the formation and destruction of opposite electrical conditions in the same points; but if a great number of points of the muscular fibre be put, by means of a good conductor, in communication with others of a different nature, which do not suffer the same chemical action on the part of the blood, the electric current should then circulate. It is this fact, furnished to us by experiment, which proves at the same time the development of electricity in the living muscle, and the impossibility for the electric current to circulate in the masses of this muscle in the natural condition."—(pp. 200, 201.)

The influence of the organic condition of the muscle is considerable. The current is less intense in the muscles of animals which have been kept without food, or in which the blood circulates feebly, or has ceased to circulate. On the contrary, in muscles, which have been for some time the seat of inflammation, or have been gorged with blood, or belong to animals that have been well fed, the muscular current shows more intensity, and continues for a longer period. The intensity of the current was not affected in frogs poisoned by carbonic acid, hydrocyanic acid, and arseniuretted hydrogen. The influence of sulphuretted hydrogen is, on the contrary, very marked; a dead animal, in an atmosphere of sulphuretted hydrogen, almost entirely loses the property.

Lecture X. on *Electric Fishes*, and the *Proper Current of the Frog;* and *Lecture XI.* on the *Physiological Action of Gravity*, *Light* and *Caloric*, which contains nothing new, we shall pass over. *Lectures XII. and XIII.* treat of the *Physiological Action of the Electric Current.*

Statical electricity produces no phenomenon on living beings peculiar to them, or different from those offered by inorganic bodies when submitted to the same influence. Such is not the case, however, with respect to the action of dynamical electricity. The assumption of Galvani of the existence of an *animal electricity*, which the metallic arc merely discharged, though abandoned after Volta's experiments with the condensing electrometer, is now regarded as far from erroneous. But the contractions excited in the frog, or in any living or recently killed animal, when one of its nerves is traversed by the electric current, are quite independent of all animal electricity. If you expose the sciatic nerve in both thighs of a rabbit, separating it as much as possible from the surrounding parts, then wipe it with some unsized paper, and introduce beneath it a band of gummed taffeta to insulate it completely from the surrounding parts, and then transmit the current from a pile of ten elements along the nerve, at the moment the circle is closed, the muscles of the thigh will contract, the animal will utter cries, and the ears be agitated. These effects are repeated when the circuit is opened, by interrupting the communication of the conductors with the nerve. This phenomenon occurs whether the direction of the current be direct or inverse. Whilst the circuit remains closed no effect is perceived.

> "Whatever be the direction of the current in the nerves, it gives rise, both at its commencement and at its interruption, to analogous phenomena; but we constantly observe, that the most violent contractions are those which are excited during the first moments of the passage of the direct current. Marianini observed, that if a man close the circuit of a pile composed of a certain number of elements, by touching one pole with one hand, and the opposite pole with the other hand, the strongest shock is always felt in that arm in which the direct current circulates.
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> "If we continue to experiment upon the same animal, all these phenomena more or less rapidly cease, according to the greater or less energy of the current, and the animal gives no further evidence of the passage of it. If the animal be then left undisturbed for some time, or, if we augment the force of the battery, the previous phenomena reappear.
>
> "But it is important to follow carefully the phenomena which take place in proportion as the action of the current upon the animal is prolonged, and before they completely cease. You will observe that, when the direct current is interrupted, the contractions of the inferior muscles (those which are placed below that part of the nerve to which it is applied) become more feeble, whereas they continue in the muscles of the back, and the agitation, and often the cries, of the animal continue. We see, also, that for the first few moments of the passage of the current, its effects are limited to contractions of the inferior muscles. When the current is reversed, the contractions of the muscles of the back, the movements of the ears, and the cries, are not manifested except at the moment of closing the circuit; while the contractions of the inferior muscles are scarcely perceptible. But the opposite effect takes place when we interrupt the circuit: that is to say, the contractions of these latter mucles continue, whilst those of the back, and the movements of the ears disappear, and the animal ceases to utter cries."
> —(pp. 246, 247.)

We must, therefore, divide into two different periods the action of the electric current on the nerves of a living animal. The current acts in the direction in which it is transmitted, when it begins to circulate in the nerve, and in the opposite direction when it ceases to circulate. If you divide transversely the spinal marrow of a rabbit, and pass an electric current along the crural nerve, the muscles situated below the point of division only contract; and if the division was effected near its inferior extremity, no contractions will occur in the muscles situated above the excited nerve.

> "The contractions excited in the muscles situated above the irritated nerve by an electric current, are then *reflex movements*. The excitation of this nerve is transmitted to the spinal marrow, and the latter, by a reflected action, produces contractions of muscles not supplied by the nerve irritated by the current. We may, therefore, say, in the language of Dr. Marshal Hall and other modern physiologists, that the electric excitation of a nerve which was at first centripetal, is transformed into a centrifugal one." * *
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> "By submitting recently killed rabbits, prepared as in the preceding experiments, to the influence of a single element, we obtain the contraction of the inferior muscles, at the moment when the circuit of the direct current is closed, and when that of the inverse current is interrupted. By acting with a more powerful battery, the contractions of the same muscles take place as well when the current begins to circulate as when it ceases, whichever its direction may be. After it has continued to pass for a certain time, contractions no longer ensue, except at the commencement of the direct, or at the cessation of the inverse current."—(p. 249.)

These phenomena may be verified by preparing a frog according to Galvani's method, and from which the bones of the pelvis, and the lumbar vertebra have been removed. The frog is so placed that each foot shall be in a glass of water.

> "When I plunge the two conductors of a pile into these glasses, you will at first observe that the frog will leap out; and if we retain it forcibly in its place, contractions take place in both legs both when opening and closing the circuit, and, consequently, in the limb in which the current is direct, as well as in that in which it is inverse. But if we continue the experiment, we soon perceive the alteration already described; that is to say, at the moment when the circuit is completed, one limb only contracts, namely, that in which the current is direct; while, on the contrary, when we interrupt the circuit, the contraction takes place in the other limb, namely, in the one traversed by the inverse current. This series of phenomena is manifested, more or less speedily, according to the strength of the current, and the vivacity of the animal, but it is never absent. Thus, then, the frog is not only a galvanoscope of extreme sensibility, but it is also an instrument which may perform the office of a galvanometer, and like this, indicate the direction of the current which circulates in a portion of its nerves." —(pp. 250, 251.)

Professor Matteucci next examined the action of the electrical current on muscular fibre alone, by depriving a muscle as carefully as possible of its nervous filaments; and he found that it excited contractions of the muscular mass, both when the circuit is closed and when it is interrupted, whatever may be the direction of the current relatively to that of the muscular fibres; and, also, that the contractions which take place when the circuit is opened, are the first to disappear.

> "If the discharge be that of a Leyden bottle, which is made to pass across a muscle,—for example, the gastrocnemius of a frog,—it is curious to observe that the muscle contracts and continues in that state."—(p. 253.)

It remains now to notice the various circumstances which modify the action of the current on the nerves and muscles of living, or recently killed animals.

> "The *voltaic alternatives*, of which I am now about to speak, are the result of the same passage of the current in the nerve. Observe in what this phenomenon consists. We put a frog, prepared in the usual way, across two small glasses, containing pure, or slightly saline water, in such a way that the spinal marrow is immersed in one glass, and the legs in the other. We then close the circuit. If we allow the current to circulate for a certain time, say twenty or thirty minutes, according to the strength of the current, and then open it and close it again, no further contractions are obtained. But by reversing the direction of the current, the contractions re-appear; and they cease again, more speedily than in the pre-

ceding one, when the passage of the current has been prolonged. By again reversing the direction of the current, that is, by re-establishing it as it was at the commencement of the experiment, the contractions reappear. These alternations may be repeated a certain number of times on the same animal. The intervals of time between the passage of the two currents, depend on the intensity of the current and the vivacity of the animal. It is easy to prove that the diminution of the excitability of the nerve from the passage of the current, is principally manifested in the portion traversed by the latter. Suppose we have passed a current through the nerve of a frog prepared after Galvani's method, and have prolonged the action until the contractions have ceased; if we then apply the conductors to a portion of the nerve more distant from the brain than that on which we first acted, we soon observe the contractions re-appear according to the laws already laid down. By continuing these experiments, exposing successive portions of the nerve more distant from the brain, similar results are obtained. We may therefore say, that the excitability of the nerve, roused by the current, retires towards the periphery according as its vitality becomes extinct. When we act on a living animal in the way described, we find that the signs of pain evinced when an electric current traverses its nerves, are also manifested when we act on those parts of the latter, nearer and nearer to the brain, according as its vivacity diminishes by the prolonged passage of the current. In both cases, it is the excitability of the nerve which becomes weakened by the passage of the current; and, as when a muscular mass is traversed by the latter, it is certain that the whole, or at least the greater part of the current passes, not by nervous filaments, but by the muscles, which are better conductors, it is natural that these filaments should preserve their excitability, and that they should be found also excitable by the current."—(pp. 253, 254, 255.)

Animals killed by hydrogen, azote, carbonic acid, and chlorine, present no difference, when the electric current is passed through their nerves, from animals dead of or from other causes. But when they are destroyed by hydrocyanic acid, or by the repeated discharges of a large battery through the spinal marrow, very slight or no contraction is produced, when the current is applied upon the nerves; but when the muscles are submitted to the same current they give evident signs of contraction; thus proving that the muscular fibre possesses the property of contracting under the influence of the electric current, independently of the nerve. But in animals who have died in sulphuretted hydrogen, no contractions are obtained, unless powerful currents are employed, and then they soon cease, whether we act on the nerves, or on the muscles. A ligature on the nerve produces no other influence than that of insulating the effects of the current; that is, of producing the effects of its action on the nervous centres, separately from those which it has when acting upon the extremities of nerves. For when the current is transmitted through the part above the ligature,—towards the brain,—on opening and closing the circuit, signs of pain and contractions of the back are manifested; but if the current be transmitted below the ligature, contractions of the leg are obtained.

Prof. Matteucci experimented to ascertain the different effects of the direct and inverse current. The general conclusions at which he arrives, are:—

1st. "The contraction excited by the electric current, transmitted along a nerve in the direction of its ramification, and which we call *direct*, is always more energetic than that which this same current produces when passing along the nerve in the opposite direction.

2dly. "The direct current weakens and rapidly destroys the excitability of a nerve; whilst the passage of the inverse current augments it within certain limits.

3dly. "To produce these effects, the action on the nerve, of the direct as well as of the inverse current, ought to be continued for a certain time, which will be longer in proportion as the excitability of the nerve is weaker."—(p. 262.)

He next notices the influence produced by repose on a nerve which has been submitted to the action of the current.

> "If the nerve has been traversed by the direct current, repose restores a portion of its excitability; if it has been traversed by the inverse current, it loses by repose a part of that excitability which it had acquired under the influence of the current. When the nerve is very irritable, a very short repose suffices to restore the excitability lost by the action of the direct current; it is the same with the augmentation occasioned by the inverse current; almost as soon as it is interrupted, the nerve returns to its normal condition. In proportion as the excitability diminishes, the duration of repose necessary for giving or arousing the excitability acquired under the passage of the current, augments."—(pp. 263–4.)

The theory of the action of the current on the nerves, and of the phenomena which it produces in animals, deduced from the foregoing facts, established by innumerable experiments, which Prof. Matteucci gives, as well as the effects of the currents on the brain, spinal marrow, roots of the nerves, nerves of sensation, and ganglionic nerves, we shall be obliged to pass over. Our author found, along with Marianini and Masson, that a repeatedly interrupted current destroyed the excitability of the nerves much more quickly than a continuous one. He describes and figures Masson's apparatus, which is highly ingenious. On submitting a rabbit to the passage of a current by means of Masson's wheel, one of the conductors of a pile of ten elements being introduced into the mouth, and the other communicating with the muscles of the back, the animal died within a few seconds; so great was the loss of nervous power in a very brief space of time.

Prof. Matteucci concludes these lectures with stating some of the therapeutical applications made of electric current, founded upon the scientific principles which he has propounded.

In paralysis he says:—

> "Abstraction being made of all purely theoretical ideas, and independently of all hypothesis of the nervous force, we may admit that, in certain cases of paralysis, the nerves undergo an alteration analogous to that which they would suffer if they had been subjected to a continued passage of the electric current. We have seen that, in order to restore to a nerve the excitability lost by the passage of this current, it is necessary to subject it to the action of the inverse current. I must add, in favour of the efficacy of the therapeutic use of this current, that a limb, although paralyzed, constantly suffers some contractions when it is submitted, either to the passage of a current or to the action of electric discharges; and these contractions favour the restoration of the functions of the muscles. Experiment confirms these ideas: divide the two sciatic nerves of a living frog, allow one of the two limbs to remain quiet for ten, fifteen, or twenty days, and submit the other, two or three times a day, to the action of the current. The latter will continue to contract, whilst the other will fail to give any contractions when the current is applied to it. I am anxious to state to you some rules which I consider as important in the application of the current to the treatment of paralysis. You should always commence by employing a very weak current. This precaution seems to me now more important than I formerly believed it to be, having seen one paralytic patient seized with true tetanic convulsions under the action of a current furnished by a single element. Take care never to continue the current for too long a period, especially if it be energetic. Apply the interrupted current in preference to the continued one; but after *twenty* or *thirty* shocks, at the most, allow the patient to have a few moments' repose. Both practice and theory seem to prove, that the interrupted current is more useful than the continued one. A pile, with Masson's wheel, or, still better, the electro-magnetic machine, is the most convenient apparatus for this purpose. Electro-magnetic apparatus are now constructed, in which the interruptions of the current are made without the necessity

> of an assistant. We may employ, as conductors, two ribands of sheet lead or copper. The extremities, which are placed in contact with the skin, should be covered with cloth moistened with salt and water. In some cases, it is useful to employ, as extremities of the conductors acupuncture needles. The number of authentic cases of paralysis cured by the electrical treatment, is already sufficiently great to encourage physicians and patients to persevere in its use. Perseverance, indeed, is indispensable in the application of the electric current, for without it, successful results are impossible."—(pp. 273, 274, 275.)

Prof. Matteucci was the first to apply the electric current in tetanus.

> "The principles on which is founded its employment for the cure of this disease are the following. A current which circulates by jerks in an animal during a certain time, produces tetanic convulsions; the direct current, if continued sufficiently long, produces, on the contrary, paralysis. From this it was concluded, that the continued passage of the latter, in a tetanized limb, would destroy this condition, by producing a state more or less allied to paralysis. The truth of this conclusion is demonstrated by facts. In operating upon frogs which have been tetanized by narcotics or hydrocyanic acid, we observe a fit of tetanus cease under the influence of the prolonged passage of a direct current. The frogs die without presenting those convulsions, which are observed take place when these animals have not been submitted to the direct current."—(pp. 275, 276.)

During the passage of the current, the convulsions were moderated; the patient was able to open and shut his mouth; and the circulation and respiration appeared to be re-established. But the amendment did not continue. With regard to vesical calculi, he observes,

> "It is sufficient, however, to remember, that the substances which compose urinary calculi are insoluble in water, to be convinced that such an application has no basis to rest on."—(p. 276.)

As for cataract, he remarks, that it is possible to create a cataract, but impossible to destroy it. Petrequin, of Lyons, has recently proposed the use of galvano-acupuncture for the cure of aneurisms, founded on the property which the electric current possesses, of coagulating the serum of the blood, and, consequently, of partially filling up the aneurismal sac.

Lectures XIV. and XV. are on *Nervous Force.* Professor Matteucci argues for, and conclusively (to us) shows, that whilst there is an analogy between the electric and nervous forces, that they are not identical. This might have been inferred from what has already been detailed.

> "We have seen that this current exists in the integrant parts of the muscles, as well as between the molecules of two bodies which enter into combination; that it circulates there without any regularity, and one might say that, as Ampère imagined, it took place in magnetizable bodies, and that it is only by an experimental arrangement that we can discover the presence of this current. We have also shown, that the nerves have no direct influence over the production of this current, and that their office is limited, in experiments on the muscular current, to that of a slightly conducting body, communicating with certain parts of the muscle." * *
>
> "*In the present state of science, and with the means of experimenting which we at present possess, no sign of the electric current is found in the nerves of living animals.*" (pp. 282, 283.)

It has been asserted, that steel needles introduced into the muscles perpendicularly to the direction of their fibres, become magnetic, especially at the moment that the muscles contract. Matteucci repeated all these experiments most carefully, but fruitlessly. He also tried the effect of introducing into an exposed nerve of living animals, the conductors of delicate galvanometers, by two points as far apart as possible, but without ever obtaining evident and constant traces of the electric current. Our author adds that, from what we know of the properties of electricity, and of the laws of its propagation, it is impossible to conceive the existence of a current circulating in the nerves. The laws of its propagation require conditions which are not found fulfilled in the nervous system; the propagation of its force is interrupted by causes which could not produce a similar effect upon the electric current.

The phenomenon of *contraction by induction*, or *induced contraction*, was discovered by Matteucci some years ago. If the nerve of a galvanoscopic frog be placed upon one or both thighs of a frog prepared in the usual manner, and the two poles of a pile be applied to the lumbar plexus, when the muscles of the thigh contract, convulsions simultaneously occur in the galvanoscopic claw, whose nerve rests upon the thighs in contraction. This phenomenon also occurs when the nerve of the galvanoscopic frog is placed upon the muscles of the thigh of a rabbit, which are made to contract by means of a current acting upon the crural nerve. Very fine layers of different substances, as gold leaf, thin and insulating lamina of mica, or glazed paper, being interposed, prevent the phenomenon. From this, Prof. Matteucci concludes:—1. That we cannot consider the induced contractions of the galvanoscopic frog to be due to the electric current; and 2. That we might, on the contrary, assume, that an electric discharge happens during the contraction of the muscles. A long series of experiments is enumerated, relative to the circumstances which intervene in producing, modifying, or destroying, the phenomenon of induced contraction, which further proves the non-identity of nervous force and electricity, though there is a certain degree of analogy between them.

> "We are, then, still ignorant of the cause of muscular contraction, and all that we know of this phenomenon are the following particulars: it is produced, even when acting at great distances from the muscle, upon the nerve, whose ramifications it receives; the integrity of the nervous filament from the point where the excitation takes place to the muscle itself is indispensable; this transmission is effected with such rapidity, that we are compelled to compare it to that of electricity, light, and radiant caloric, propagating itself through various media; what modifies, augments, or destroys the accomplishment of the chemical physico-phenomena of the nutrition of the muscle, has an analogous action upon its contractability, provoked by any influence acting upon the nerves; and, lastly, in the laws of the contraction of a muscle, we find an analogy with the physical laws of elasticity."—(p. 319.)

The fact of induced contraction will, then, be a phenomenon of induction of this unknown force, which circulates in the nerves, and produces muscular contraction. Prof. Matteucci proposes to call, henceforth, this new phenomenon of nervous force, *muscular induction*, instead of induced contraction.

In conclusion, we shall give the following summary of Matteucci's hypothetical views respecting the nervous force, from the *Comptes Rendus*, (15th March, 1847,) appended to these lectures, by the editor, Dr. Pereira.

> "1. The nervous fluid is produced by the chemical actions of nutrition.
>
> "2. This fluid, developed principally in the muscles, is diffused there, and being endowed with a repulsive force between its parts, like the electric fluid, retains the elements of the muscular fibre in a state of repulsion analogous to that presented by electrified bodies.
>
> "3. When this nervous fluid ceases to be free in the muscle, the elements of the muscular fibre mutually attract each other, as we see happens in cadaveric rigidity.
>
> "4. This nervous fluid enters continually into the nerves, and from them passes

to the brain, assuming in these bodies a new state, which is no longer that of the free fluid: in this manner it passes from the muscle to the nerve. According to the quantity of this fluid which ceases to be free in the muscle, the contraction is more or less strong.

"5. This state is that of the nervous current, or species of discharge which proceeds from the nervous extremities to the brain, and returns in the contrary direction, by the act of the will.

"6. When this discharge takes place, muscular contraction ought to take place, the fluid ceasing to be free in the muscles.

"7. This discharge of nervous fluid, acting as in the electric fish, explains the induced contraction; in both cases, and by the same disposition of parts, the nervous current produces a species of electric polarization of the elements, either of the muscular, or of the electric apparatus: the difference of effects will be due to a different number of elements, to their dimensions, &c.

"8. The electric current impedes the nervous discharge, if it be directed in the contrary direction; as in the direct current: the nervous fluid not being able to enter and accumulate in the nerve, this loses its excitability. The contrary takes place for the inverse current, which goes in the same direction as that of the nervous discharge: the nervous fluid is found accumulated in the nerve, and its excitability is augmented."—(pp. 326, 327).

Lectures XVI., XVII., XIX., and *XX.*, are excellent and well digested summaries on *Muscular Contraction*, *Animal Mechanics*, the *Circulation of the Blood*, the *Vocal Apparatus and Voice*, *Hearing*, and *Vision*. They contain no original observations of value, being chiefly compilations, most cleverly done, however. We must be content with referring our readers to the volume itself, which is now in course of re-publication in this country.

We cannot dismiss this admirable work, without expressing our conviction of its intrinsic worth; an opinion with which, we think, the reader of our imperfect analysis will agree. These lectures are a timely and precious contribution to physiology, and will hold there an honoured place, characterized by their accurate and philosophic character. In distinguishing the physical from the vital phenomena of living beings, and referring them to their proper laws, Professor Matteucci has laid the foundation of a new branch of science. An ingenious and skilful experimenter, his generalizations are cautious and trustworthy. He has gone to his task in a right spirit; and science is deeply indebted to him. Throughout the volume he has carefully kept in view the promise made in his first lecture, and fully redeemed it.

"In these lectures I propose to myself another, and not less important object; it is to introduce, in the exposition of physiological facts, and in the investigation of their laws, that precision of language, that exactitude of expression, that rigorous method, which are too often discarded in the study of physiology and of medicine, and which have been hitherto almost exclusively characteristic of the physical sciences."—(p. 14.)

M. C.